

SECTION I. DATA COMPILATION AND ANALYSIS

Introduction

Development of a comprehensive data base is necessary so that: (1) a base line of water quantity and quality can be established and be available for comparison to that previously acquired or collected or predicted in the future. It is also important to future decision making that such a data base be presented and interpreted in a clear fashion in a single document. (2) The construction of both a numerical flow model and a water quality monitoring program rests on a good data base.

The procedure which we will follow for data base line development is (a) collection of existing data; (b) synthesis of data into graphics, charts, tables, etc.; (c) interpretation, with emphasis on needed field data; (d) collection of field data; (e) inclusion of new data and synthesis into a final report.

Specific Work Items

A literature search will be performed, both in Tucson and in Albuquerque, with particular assistance from U.S.G.S. and B.I.A. Special attention will be paid to locate sources and include their data. Maps, drawings, and tables will be included in a working report which (1) shall show well data, potentiometric surfaces, transmissivities and hydraulic conductivities, surface



floors, withdrawal, other hydrologic information in the project area. (2) The report shall incorporate geologic data into proper form for construction of a hydrologic numerical flow model. Detailed cross sections, isopach maps, outcrops, extent of aquifer units, faulting, and volcanics shall be included. (3) The report shall show background water quality, geochemical boundaries, water chemistry relationships with time, geology, and human activities. Point, line, and diffuse pollutant sources shall be identified and delineated on maps and drawings.

During and after working report preparation a preliminary interpretation of the data shall be made with particular emphasis on the need for additional field data. These might include pump tests, standard quality analysis, carbon-14 dating (which could give information on transmissivities), halocarbon dating (Thompson 1979), isotopic fractionation analyses, total alpha, radium, uranium, and radon analyses.

These new data will be assimilated into the working report so that they can be incorporated into the numerical model and water quality monitoring³ program. After further interpretation, the working report will be refined and converted into the first part of the final report: the present status of the quality and quantity of the water resources of the Pueblo of Laguna.

SECTION II. PROPOSED NUMERICAL MODELING WORK

Introduction

The numerical modeling to be performed under this contract will consist of developing a regional ground water flow model to assist in the estimation of the effects of ground water withdrawals for uranium mining and milling on the water resources of the Pueblo of Laguna. The areal extent of the model will be sufficient to evaluate the behavior of the Jurassic aquifers under the reservation and to a distance of at least 60 miles north of the northern boundary of the reservation. The vertical coverage of the model will be sufficient to evaluate spring flows on the reservation, but will depend on the extent of interaction between the Jurassic aquifers and the surrounding water bearing units.

Specific Work Items

The numerical model will be used to assist in defining the present head distribution and pattern of ground water movement in the Westwater and Jackpile members of the Morrison Formation, including discharges to the land surface. The model will also be used to estimate the natural head distribution and flow patterns which existed before artificial withdrawals from the aquifers began ("steady state"). Finally, the model will be used to evaluate the future response of the aquifer system and associated springs and streams to predicted withdrawals for uranium mining and milling, and other relevant withdrawal uses through the year 2030.

Requirements of the Modeling Technique

Although the specific modeling technique to be used for this work cannot be specified at the present time, the hydrogeologic characteristics of the study area place certain constraints on the choice of method.

First, the Jurassic aquifers probably cannot be treated as an isolated system due to leakage to and from surrounding aquifers through confining beds and along fault zones. For this reason, the model must be capable of handling multiaquifer problems.

Second, the region is characterized by relatively small areas of heavy withdrawals and large areas of small withdrawals. Accurate results in areas of heavy withdrawals requires use of a detailed numerical grid while computer storage and time limitations necessitate using coarse grids in areas of small hydraulic gradients. To handle these requirements for a regional model, flexibility in grid design is highly desirable. The complex geologic structure in some parts of the study area, especially the Rio Puerco Fault Belt, also necessitates use of a fully three-dimensional model with a flexible grid design.

A large part of the modeling work will be devoted to analyzing the effect of withdrawals from the aquifers on spring flow. When flowing, the springs represent constant head hydraulic boundaries, but the possibility that some of the springs may cease flowing due to pumpage requires that the model be able to handle time variant boundary conditions.

Description of Possible Modeling Techniques

Three existing computer programs are available which can meet all or part of the above requirements. The three-dimensional finite difference program developed by Trescott (1975) appears to be capable of handling the multiaquifer regional flow aspects of this study. The rectangular grid requirements of this model, however, may limit its ability to accurately simulate both regional flow and flow in areas of heavy withdrawals. In addition, the complex geology of the Rio Puerco Fault Belt may be difficult to handle with this model.

An integrated finite difference model known as TRUST capable of handling three-dimensional problems is also available. A distinct advantage of this model is that it does not require a rectangular grid. This feature greatly enhances its ability to simulate areas of steep hydraulic gradients and complex geology in regional flow problems. The integrated finite difference method is described in ^{Narasimhan} ~~Narasimhan~~ and Witherspoon (1976).

A computer program known as FLUMP, which uses the finite element method, is also available for use on this problem. FLUMP has all of the advantages of TRUST with the additional capability of handling anisotropic hydraulic conductivity. Modifications of FLUMP would be required to handle the multiaquifer aspects of this study and for this reason, FLUMP probably will not be used unless anisotropy proves to be a significant factor in the area. The numerical approach used in FLUMP is described in ^{han} ~~Narasimhan~~ and others (1978).

Although every effort will be made to handle all aspects of this study with the regional model, the complex hydrogeology of some parts of the study area may necessitate developing local models. Use of local models will, however, be limited to the analysis of specific problems.

Model Calibration and Analysis of Results

The numerical model constructed under this contract will be calibrated by attempting to use it to duplicate historical water level data. The quality of the calibration will depend on the quality and quantity of hydrogeologic data available on the study area. For this reason, precise calibration cannot be guaranteed at the present time. In addition, when assumptions about hydrogeologic properties must be made, emphasis will be placed on the hydrologic reasonableness of the assumptions rather than their ability to force the model to match historical records.

Use of the model to predict the impact of future ground water withdrawals will be based as much as possible on existing scenarios of ground water exploitation in the area. If the predictions show that a scenario results in hydrologically unreasonable effects, simulation of that scenario will be terminated. For example, a particular scenario could result in lowering the piezometric surface below the top of a confined aquifer. In such an event, simulation of that scenario will not extend beyond the time when the unrealistic effect occurs.

The results of the model simulations will be presented in the form of maps and cross sections showing the piezometric surface and flow patterns, water level change maps, and spring hydrographs with textual interpretation of the results. In addition, the model results will be incorporated in the other hydrologic analyses performed under this project.

SECTION III. PROPOSED WATER QUALITY MONITORING⁰ DESIGN PROGRAM

Introduction

The monitoring⁰ program to be designed under this contract must accomplish the following goals: (1) Identify information necessary for the verification of the study projections and detection of changes in quality of reservation water resources. (2) Evaluate the results which may be obtained from the monitoring program in light of the costs involved so as to obtain the most effective program. (3) Implement a continuing monitoring⁰ program.

In order to accomplish these goals, the monitoring⁰ program must meet several requirements. The program should be designed with the particular geologic, hydrologic and geochemical characteristics of the area in mind. A generalized format will not suffice. Both present and future potential pollution sources should be considered. The program should be created with the foresight and flexibility to deal with future development. Potential pollution sources and pollutants should be evaluated in light of the volume produced, the toxicity, and the present and

projected water utilization on the reservation. Hydrologic, geologic and chemical factors which may alter the pollutants after release must be included. Finally, the program must be designed in full cognizance of present monitoring efforts, so as to be comprehensive while avoiding duplication.

Proposed Methodology

The monitoring program to be designed under this contract will utilize the methods presented in Monitoring Ground Water Quality: Monitoring Methodology, by Todd et al., 1976, published by the U.S. Environmental Protection Agency. This carefully thought-out methodology fulfills all of the requirements stated above. The major disadvantage of this methodology is that it is intended only for ground water monitoring. However, with minor modifications, this approach is readily applicable to coupled ground water-surface water systems.

Several advantages will result from the use of this methodology. Its explicit nature will allow evaluation at any time of the progress of the project and its accomplishments. It will also ensure continuity in the event of personnel changes. The use of a standard, EPA published methodology will facilitate comparison of this project with government sponsored projects of similar goals and ease cooperation between them.

Finally, in the event that the results of the monitoring program are needed as a basis for official action, the ability to

present a standard, EPA published methodology as the basis of the monitoring program will be an asset.

The methodology is divided into 15 steps, outlined below:

1. Definition of monitoring area. This will be accomplished on the basis of the hydrogeologic boundaries of the region influencing the water resources of the pueblo.

2. Identification of pollution sources, causes, and methods of waste disposal. Much of the research necessary for identification of hydrologic alterations included in the ground water flow model will be applicable to this step.

3. Identification of potential pollutants. Although radionuclides are the major concern in uranium mining and milling pollution, non-radioactive pollutants must not be neglected. Recent investigations in the ^rGiants Mineral Belt have shown nitrate and selenium to be of concern (Kaufman, Eadie, and Russell 1976).

4. Definition of water usage. This will include projected and potential usage of surface and ground water, as well as present usage.

5. Definition of hydrogeologic framework. The ground water flow model developed as a part of this project should greatly elucidate the characteristics of the hydrogeologic framework.

6. Study of existing water quality. Historical data will be very important, as already-existing mining operations have probably considerably altered the original water quality.

7. Evaluation of infiltration potential of wastes at land surface. This information is necessary for both flow model and monitoring program.

8. Evaluation of mobility of pollutants from land surface to water table.

9. Evaluation of attenuation of pollutants in saturated zone and in surface water bodies. Effects such as dilution, precipitation and entrapment in stream bottom sediment are considered here. Many radioisotopes may be attenuated by these and other processes (Card and Jansen 1975).

10. Ranking of pollution sources and causes. The benefits obtained from the monitoring program must be viewed in light of the potential damages which would result were no monitoring practiced.

11. Evaluation of existing monitoring program. The capabilities of existing programs will be compared with the ranked pollution sources and causes.

12. Establishment of alternative monitoring programs. A variety of possible monitoring programs, of varying cost and effectiveness, will be proposed. These will include monitoring alternatives in the frequently neglected vadose zone.

13. Selecting and implementation of monitoring program. After suitable alternatives are formulated all parties involved may participate in the selection and personnel training procedures of the most appropriate program which will be included in this step.

14. Review and interpretation of monitoring results. The monitoring program design must include provisions for

continuous review and evaluation of data produced, with changes in the program initiated in response to the changing situation. The program should not degenerate into an endless mechanism for the collection of no-longer-useful data.

15. Summarization and transmission of monitoring information. The results of the monitoring program must be readily available to those with responsibility for the reservation's water resources, and provision should be made for the timely communication of alarming water quality trends to appropriate authorities.

Additional Considerations

Although the Monitoring Methodology serves its purpose very well, monitoring considerations will not be restricted to its contents. The area involved presents certain particular complexities in water quality interpretation. The pollutants from the major sources in the area, the uranium mines and mills, originate from native materials, not imported ones. The results of water quality analyses may be ambiguous, inasmuch as the products of mining and milling may be difficult to distinguish from the products of the leaching of natural, in situ, mineral deposits.

One solution to this problem is the use of hydrologic "tracers," both natural and artificial. One natural tracer which should be seriously considered is the isotopic composition of the sampled water. The high evaporation rate of tailings and seepage

ponds tags the resulting water with a readily identifiable, heavy isotopic composition.

Artificial tracers which may be introduced to the ponds without any adverse environmental effects are certain halogenated hydrocarbons, or halocarbon compounds (Thompson 1979; Davis et al. 1979). Were these halocarbons later detected in surface or ground water, contamination from disposal ponds would be unambiguously indicated. Both the natural isotopes and the halocarbons exhibit characteristics which are very appropriate for tracers: they are not readily subject to chemical change (other tracers such as ^{nitrate}~~intrater~~ can be degraded), they are non-toxic, very small amounts of changes are detectable. Fluorocarbons are easily detectable in the low part per trillion range which increases sensitivity and reduces expense. Also several tracers can be measured in the same analysis which enables several tracer input sources to be monitored very easily in contrast to virtually all of the major possible pollutants. This important characteristic means that the detection of the tracers can give early warning of harmful pollutants which travel more slowly. One of the aspects of the monitoring design will be an evaluation of the effectiveness of these and other tracers in the Laguna area.

The end result of the design project will be the implementation of an effective, efficient, dynamic monitoring program which will define present problems and adapt to those of the future.

TIME SCHEDULE

Time from Contract
Execution Data

Section I. Data Collection and Analysis

The bulk of this study will be completed in two months from award of contract. Some additional data will come in more slowly, depending on interpretation and collection. Because of high initial radon content, the carbon-14 results will be delayed for about three months (so that the radon can decay away).

Initial data--2 months
Total time--5 months

Section II. Numerical Model

Model choice, construction, programming, and calibration will take about eight months from reception of initial data from Stage I. Results of scenarios and report preparation should not exceed an additional month.

11 months

Section III. Water Quality Monitoring

Evaluation of present situation and detailed construction of a water quality monitoring program should encompass about eight months from reception of Stage I initial date.

10 months

Report

The draft report should be ready in eleven months from contract award. Final report depends on length of review process, but should not exceed the one year time limit for contract term.

12 months